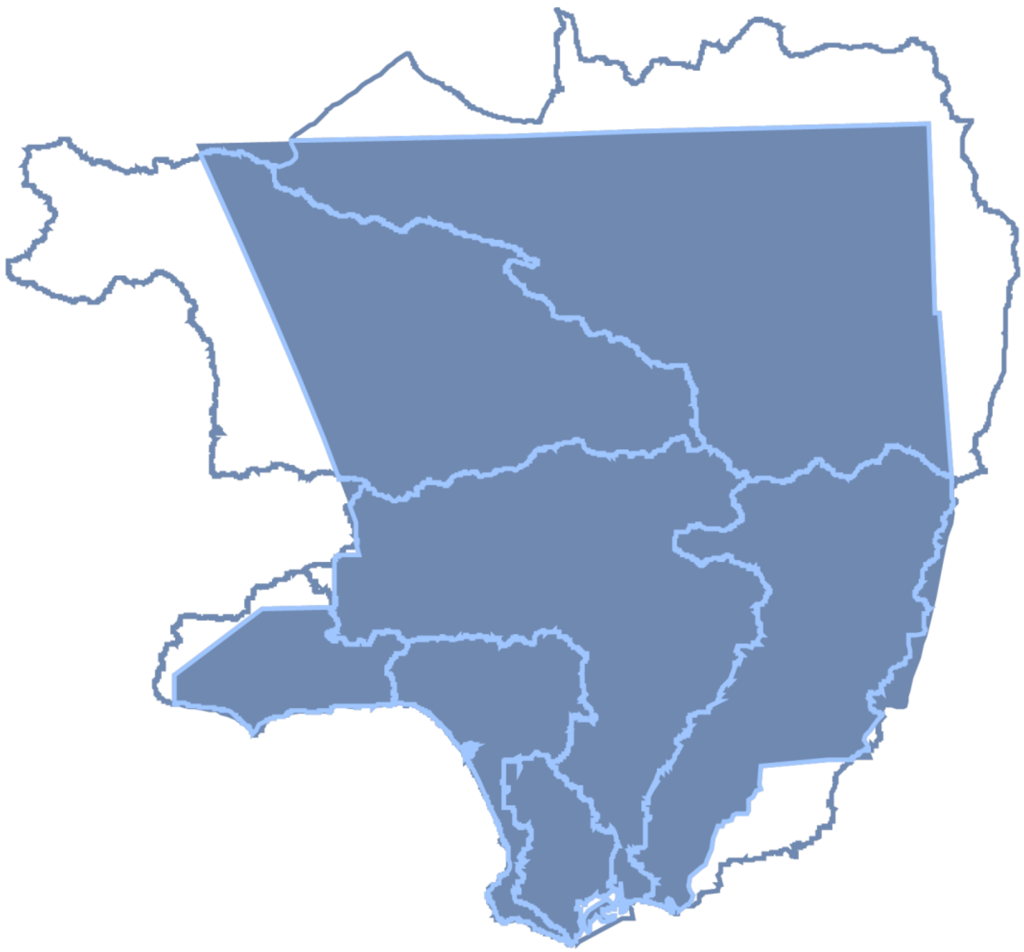
The Los Angeles County Watershed Management Modeling System Regional Optimization User's Manual



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Contents

1. Installation

The Los Angeles County Watershed Simulation-Optimization Package (LAC-WASOP) software package consists of three major components:

- MapWindow open source GIS environment
- LAC-WASOP software (a MapWindow add-on)
- Data (spatial, temporal, and model configuration files)

Correspondingly, the installation deliverable (in the forms of CD, DVD, or FTP downloads) include these three folders:

.\MapWindow\

.\LAC-WASOP\

.\DATA\

The entire installation process consists of three steps.

Step 1: Install the MapWindow GIS software.

The installation file is in the folder .\MapWindow. To install MapWindow, use your Windows Explorer to browse to the .\MapWindow folder. You should see the installation file MapWindowx86Full-v48RC1-installer.exe. To start the installation process, double-click that file. Follow the screen prompts to complete the installation process.

Step 2: Install the LAC-WASOP core model

After the MapWindow GIS software is installed, use your Windows Explorer to browse to the folder .\LAC_WASOP\, which holds the installation file LSPC_MapWindow.msi. To start the installation process, double-click the file. Follow the screen prompts to complete the installation process.

Step 3: Install the data files

On your local C: drive, create a folder named C:\LA_MapWindow, and then copy the entire .\DATA folder (including its subfolders\DATA\shapefiles\, .\DATA\Weather, and .\DATA\Database) into it, such that you have the following folder structures on your computer:

- C:\LA_MapWindow\DATA\Shapefiles\, which includes shapefiles of the GIS coverage of the entire LA County LSPC watershed model, and compliance points for water quality impairments
- C:\LA_MapWindow\DATA\Weather\, which includes all the weather files for the entire LA County LSPC watershed model
- C:\LA_MapWindow\DATA\Database\, which includes a Microsoft Access database file:
    - LSPC_V4-1-0_LAC-WASOP.mdb: includes the necessary coefficients for the LA-WASOP system

After completing the three installation steps, you can use the LAC-WASOP system.
Note: The LA-WASOP system is built on a new algorithm for solving simulation-optimization models, which is named NIMS (Nonlinearity-Interval Mapping Scheme). NIMS is a recently developed algorithm for efficiently solving models. It provides a unique capability for solving large-scale simulation-

optimization models that were computationally prohibitive if using other existing algorithms. For details of the theoretical derivation and algorithmic process, see Zou et al. 2010a; Zou et al. 2010b. The NIMS code developed for this system uses a commercial optimization modeling software Lingo 12.0 as the core solver for the intermediate sub-models. Before using the LA-WASOP system, you must have a top level license of Lingo 12.0 that allows an unlimited number of constraints and decision variables to be installed in their computers. Although the system allows the user to select smaller subsets for optimization, top level Lingo flexibility is required for running the full-scale watershed optimization problem. A demo version of LINGO has been provided in the installation package.

2. Using the Software

The LAC-WASOP system is organized by project (or scenario), where one folder contains all files associated with a particular analysis scenario. This section describes how to create a new project from a blank MapWindow screen. It describes the process for (1) importing GIS features, (2) creating a folder structure for organizing files, and (3) creating the necessary linkages and model configurations for running watershed-scale optimization. To create a new project, follow the steps listed below.
The configuration process for both database files follows the same general sequence. When applicable, special instructions for the Reservoirs database are added in red text.

Step 1: Start the MapWindow GIS interface.

To start the interface, double-click the MapWindow icon on the desktop or launch it from the Windows Start menu. After you launch the program, you should see a screen like Figure 1.

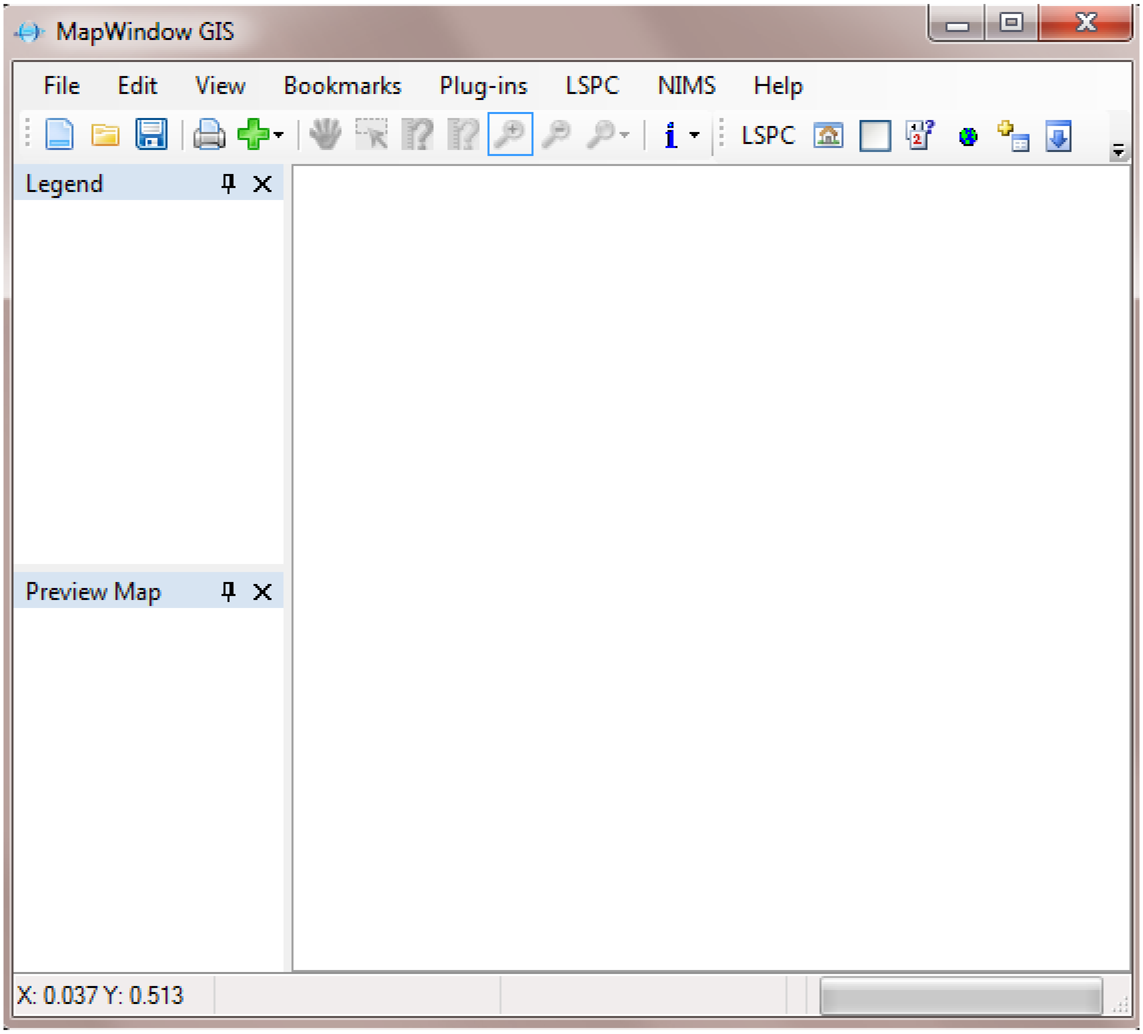


Figure 1. The initial MapWindow GIS interface.

On the menu bar click **Plug-ins** and select **Edit Plug-ins** (Figure 2).

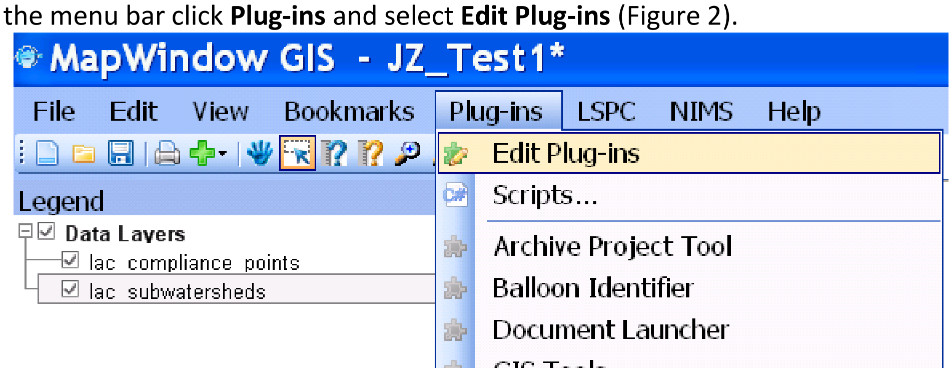


Figure 2. Selecting Edit Plug-ins.

At the bottom of the Edit Plug-ins list, check **Watershed Models: LSPC Map Tools** (see Figure 3), and click **Apply**. The **LSPC** and **NIMS** menus are activated.

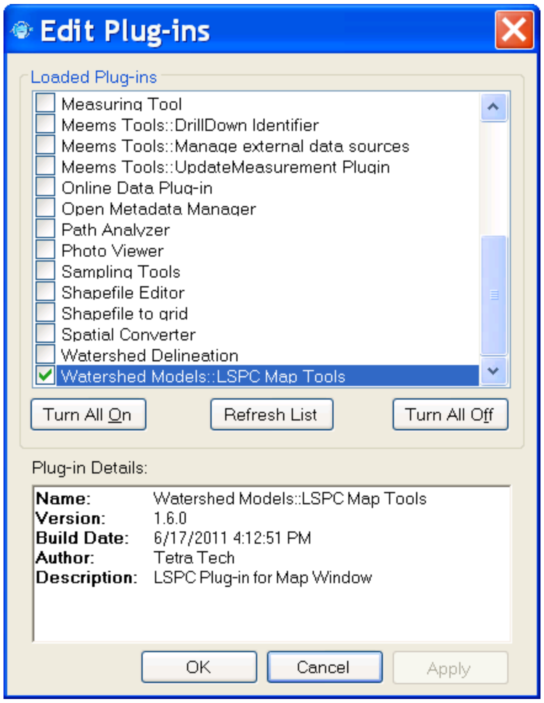


Figure 3. The edit Plug-ins dialog box.

Step 2: Creating a new MapWindow project

Click **File**, then **New**, then move the mouse pointer to the + icon as shown in Figure 4. The message "Add/Remove/Clear Layers" appears. Click the + icon on the toolbar, and use the browser to browse to the folder where the shape files are located (Figure 5). Then, to add the shape file into the project, double-click the file lac_compliance_points.

Repeat the process to add lac_subwatersheds into the project. After that, the MapWindow interface should look like Figure 6.

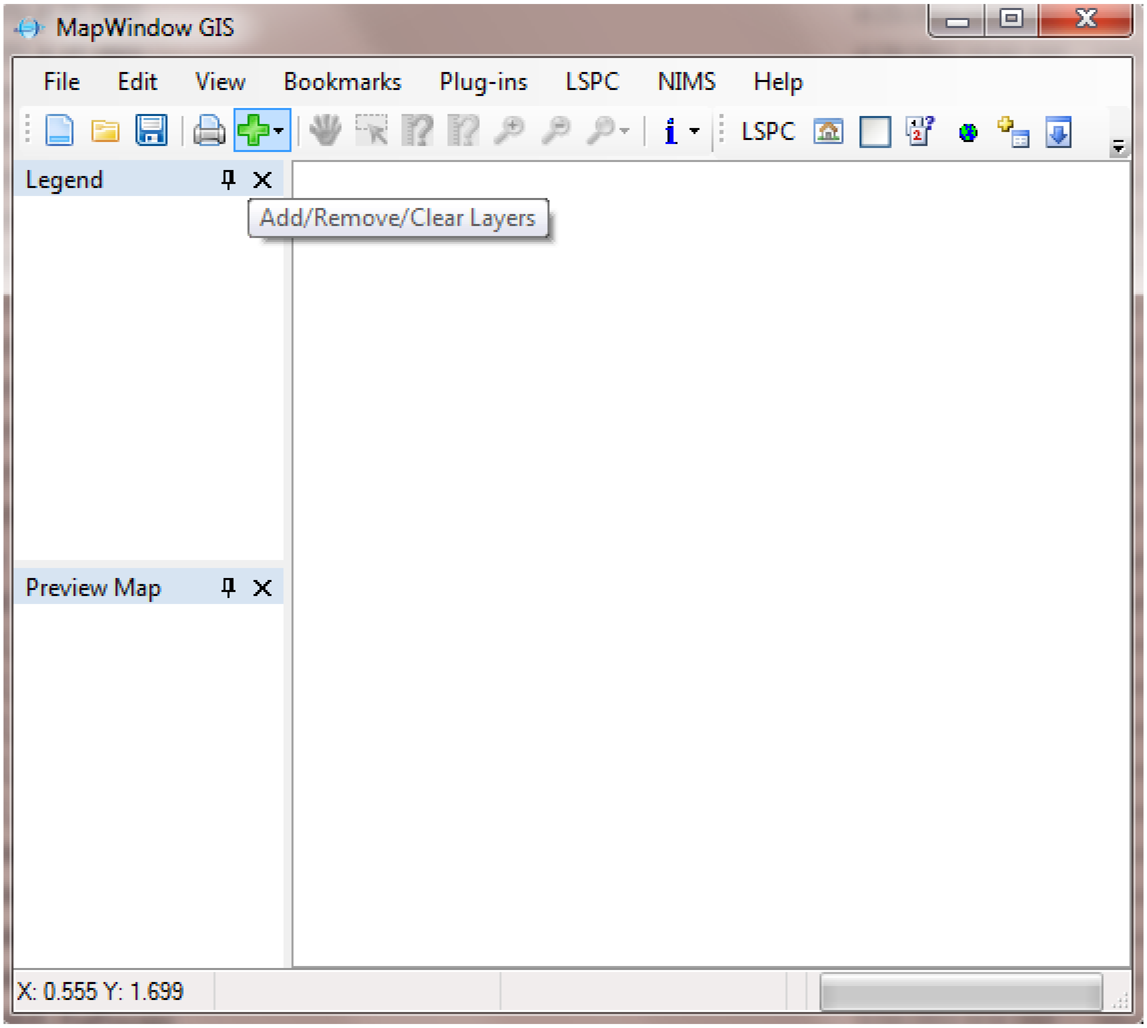


Figure 4. Creating a project (part 1).

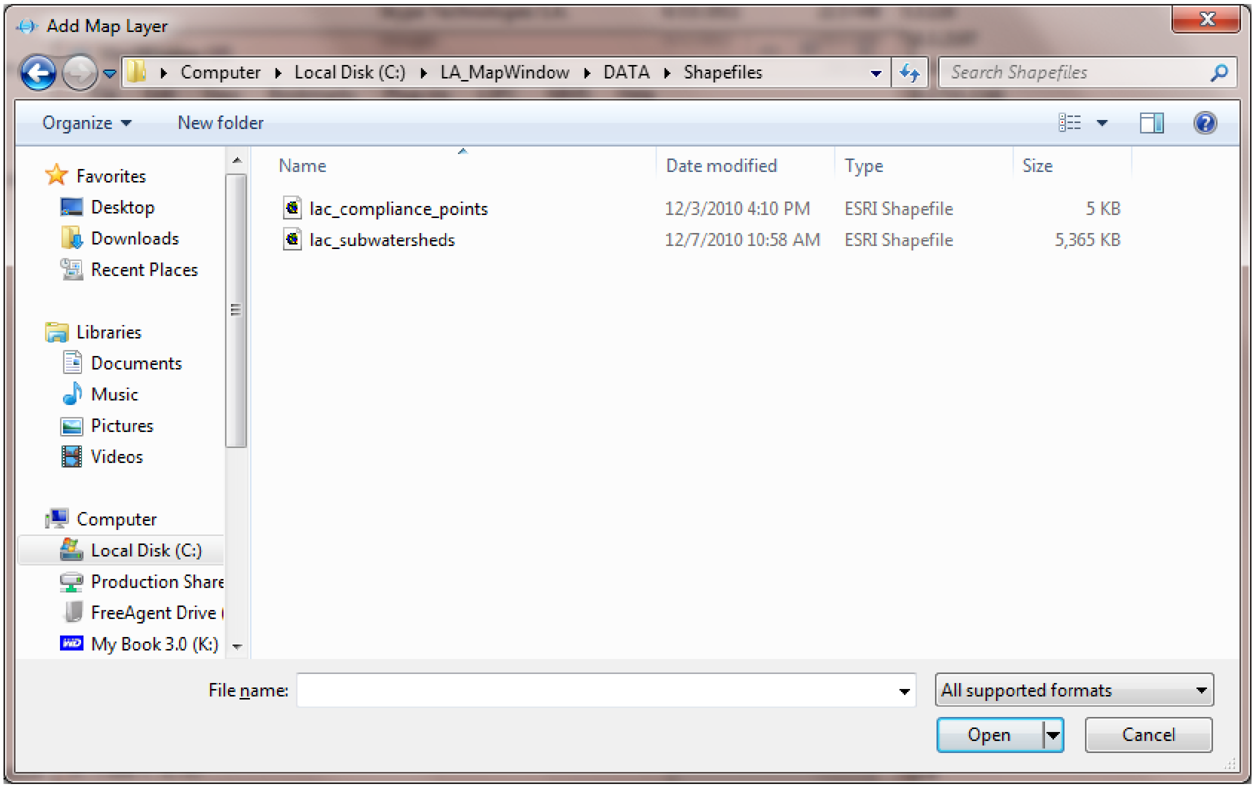


Figure 5. Creating a project (part 2).

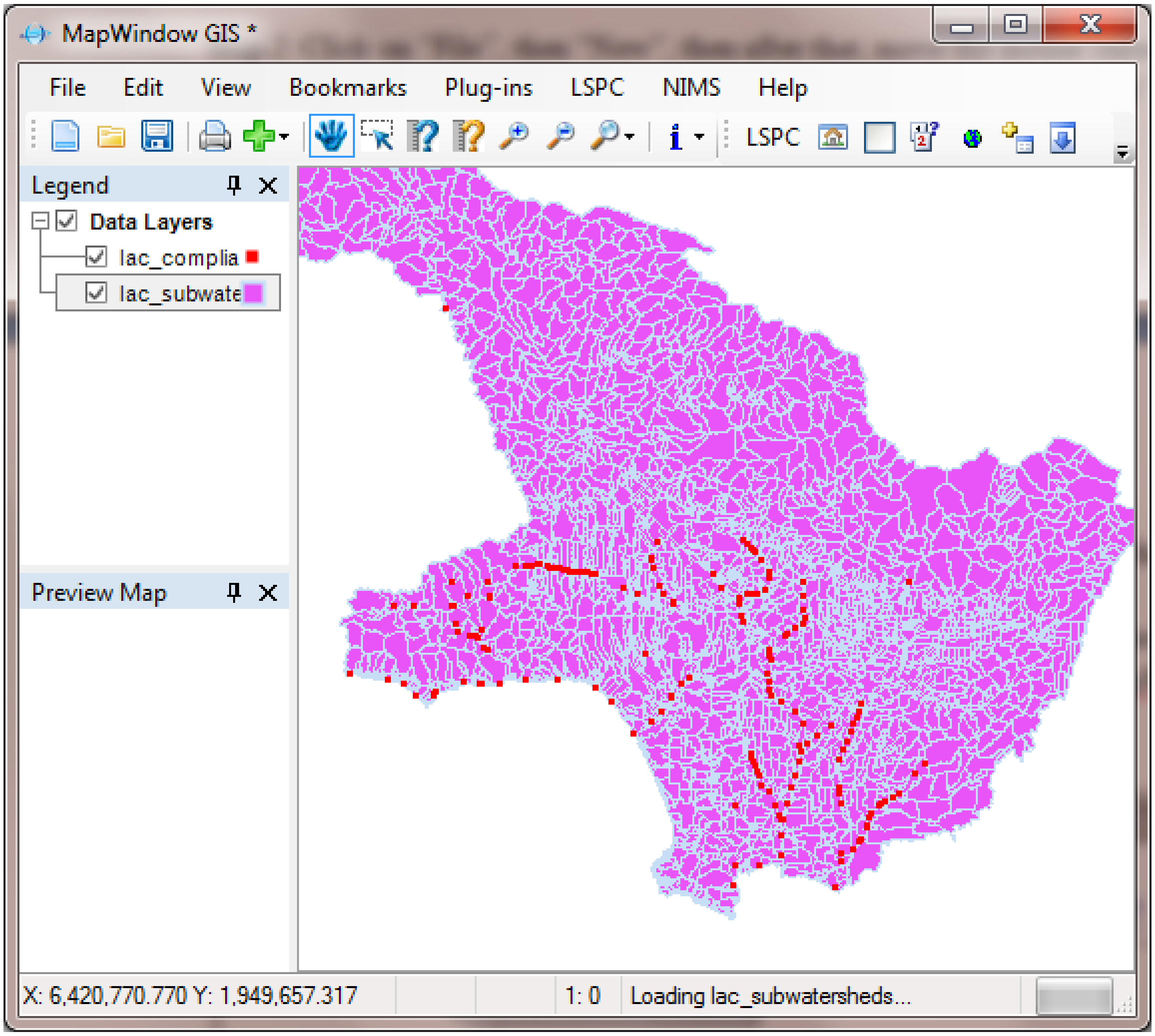


Figure 6. A created project.

Step 3: Save the MapWindow project

To save the project in a specified directory, cick **File**, then **Save As**. For example, you could save the project to a name `LA_WASOP_Test1` under the folder `C:\LA_MapWindow`.

Step 4: Configuring LSPC Map Tools Settings for NIMS

Click the **NIMS** menu, which displays the application menu as shown in Figure 7. Click the **Modify LSPC application settings** menu item, which displays the LSPC MapWindow application setting window as shown in Figure 8. Fill in proper values in each line of the the LSPC MapWindow application setting window using the information below.

Subbasins Layer: For this item, browse to C:\LA_MapWindow\DATA\Shapefiles, and select lac_subwatershed.shp

Subbasin Field: From the dropdown list, select **NEW_WSID**

Down Stream Field: From the dropdown list, select **NEW_DS_ID**

Compliance Point Layer: You can leave it blank, or browse to C:\LA_MapWindow\DATA\Shapefiles, and select `lac_compliance_points.shp`
Subbasin Field: Leave blank
LSPC Database: Browse to the folder C:\LA_MapWindow\DATA\Database, and select the `.mdb` file.
LSPC Output Table: From the dropdown list, select **LSPC_Unit/Areal**. Currently there is only one item in the list.
LSPC Output Join Field: From the dropdown list, select **SUBBASIN**
Start Color: Leave unchanged
End Color: Leave unchanged
Color Breaks: Leave unchanged
NIMS Installation Path: Browse to the folder where the LA-WASOP core model is installed. On a Windows 7 computer, the path is likely to be

C:\Program Files\MapWindow\Plugins\WatershedModels\LSPC

Project Path: Specify the folder where you will store the scenario analysis. It is recommended that the project path would be a new folder under `C:\LA_MapWindow`. For example, if a scenario name *Study1* is to be used, enter: `C:\LA_MapWindow\Study1`. Make sure that a `.\Study1` does not already exist. The software creates a folder for the project. To avoid problems with system configuration, you should specify a new folder every time you create a new scenario.
Number of Runs: Input the number of LSPC runs that will be used to construct the interval matrix for implementing the optimization algorithm NIMS. To allow the model to be able to obtain optimal solutions, a relatively large number of runs is needed however, too many runs could result in significant computation time. For the first try, a number *7* is recommended.
Start Time: Input the starting time for the continuous simulation. In the LA County model, the recommended starting time is **10/01/1993.**
End Time: Input the end time for the continuous simulation. The recommended value is **09/30/2006**
Output Start Time: Input the start time for simulation model output, which will be taken into account in load calculation. Set the value to **10/01/1996.**
Output End Time: Input the end time for simulation model output, which will be taken into account in load calculation. Set it to **09/30/2006**.
Weather Folder (optional): Input the folder path where the weather files are stored. If it is left blank, the model default is `C:\LA_MapWindow\Weather`. If the weather files are stored in another location, such as `C:\LA_MapWindow\DATA\Weather`, enter the corresponding folder here.
Degree of Practice (75-100): Specify the desired degree of practice for each analysis. The degree of practice denotes the willingness for allowing certain percentage of exceedance of pre-specified water quality target. For example, 75 indicates that 25% of exceedance is allowed in a scenario

An example of the filled LSPC application settings form is shown in Figure 9. After all the values are filled, click **Save**, and then **Close**.

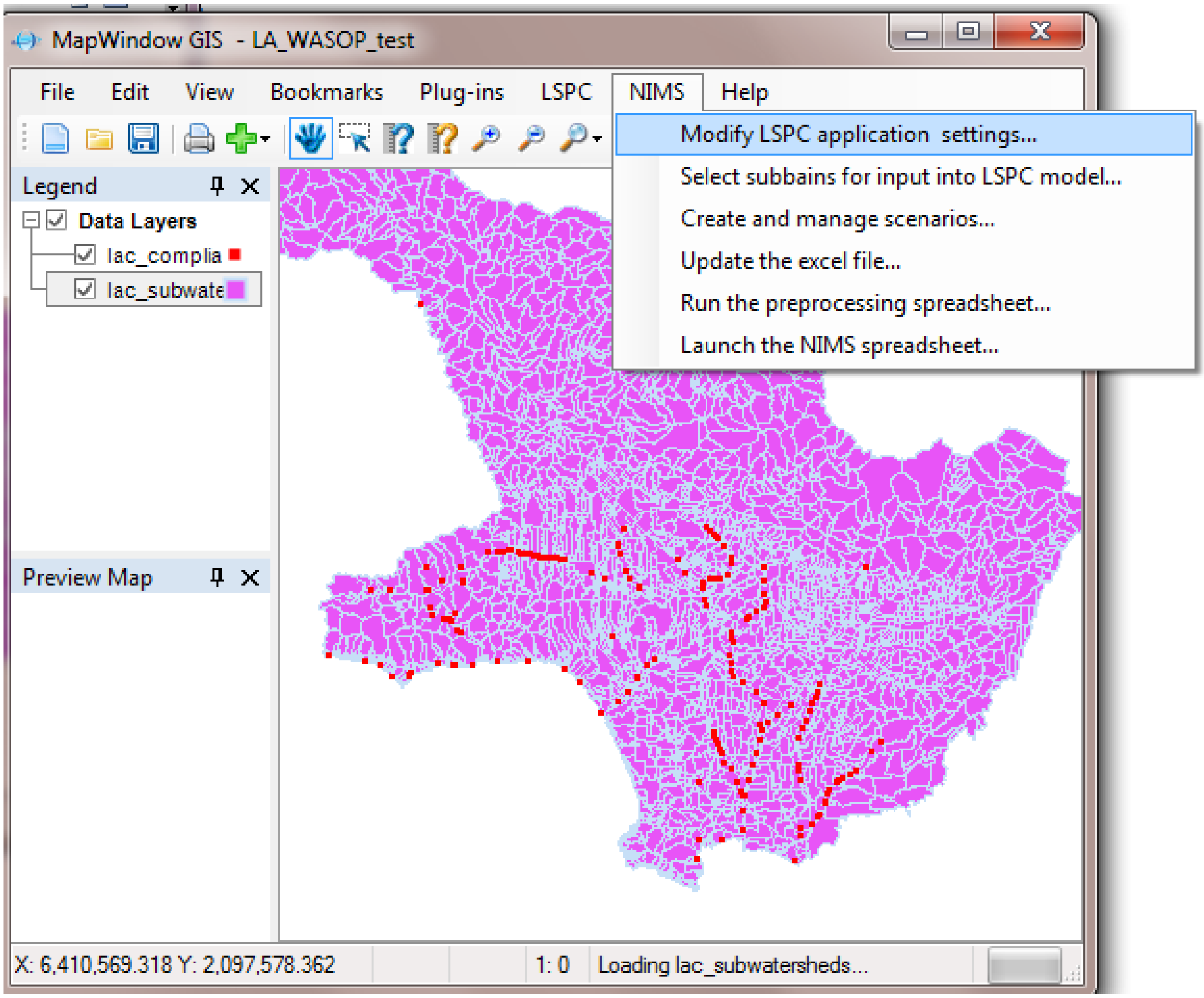


Figure 7. The activated project application menu.

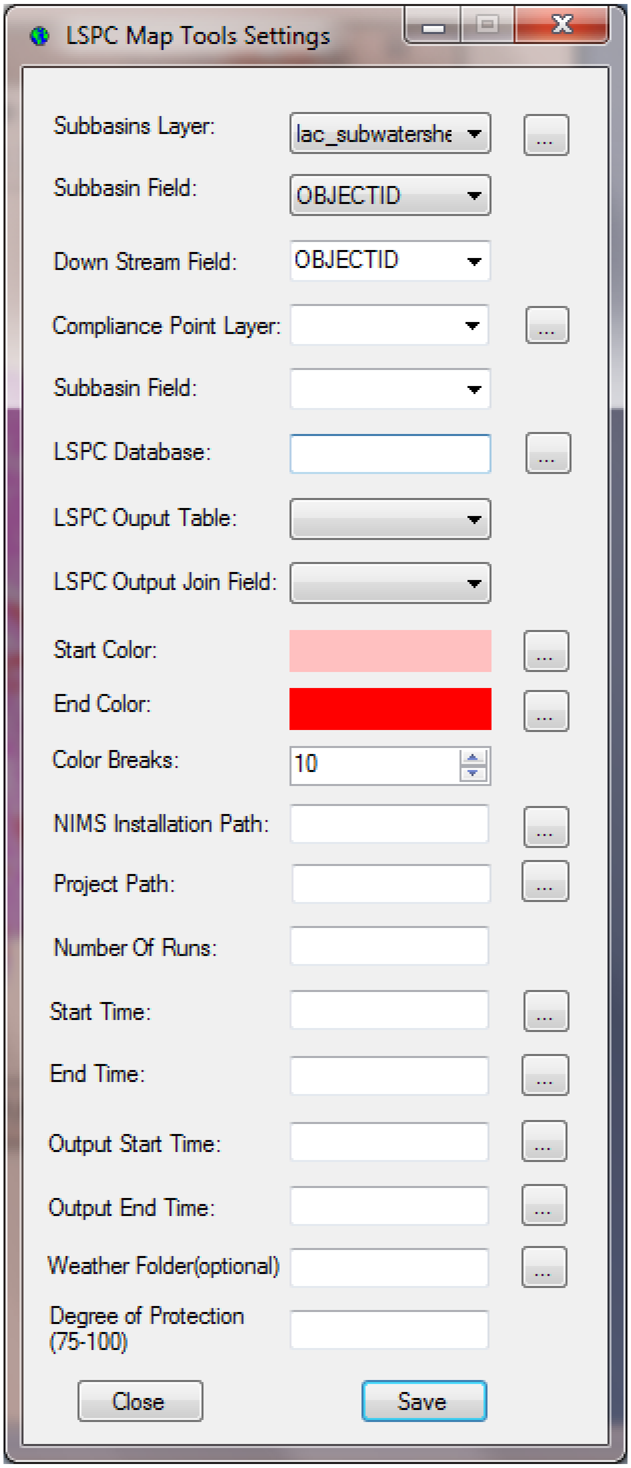


Figure 8. The LSPC Map Tools settings window.

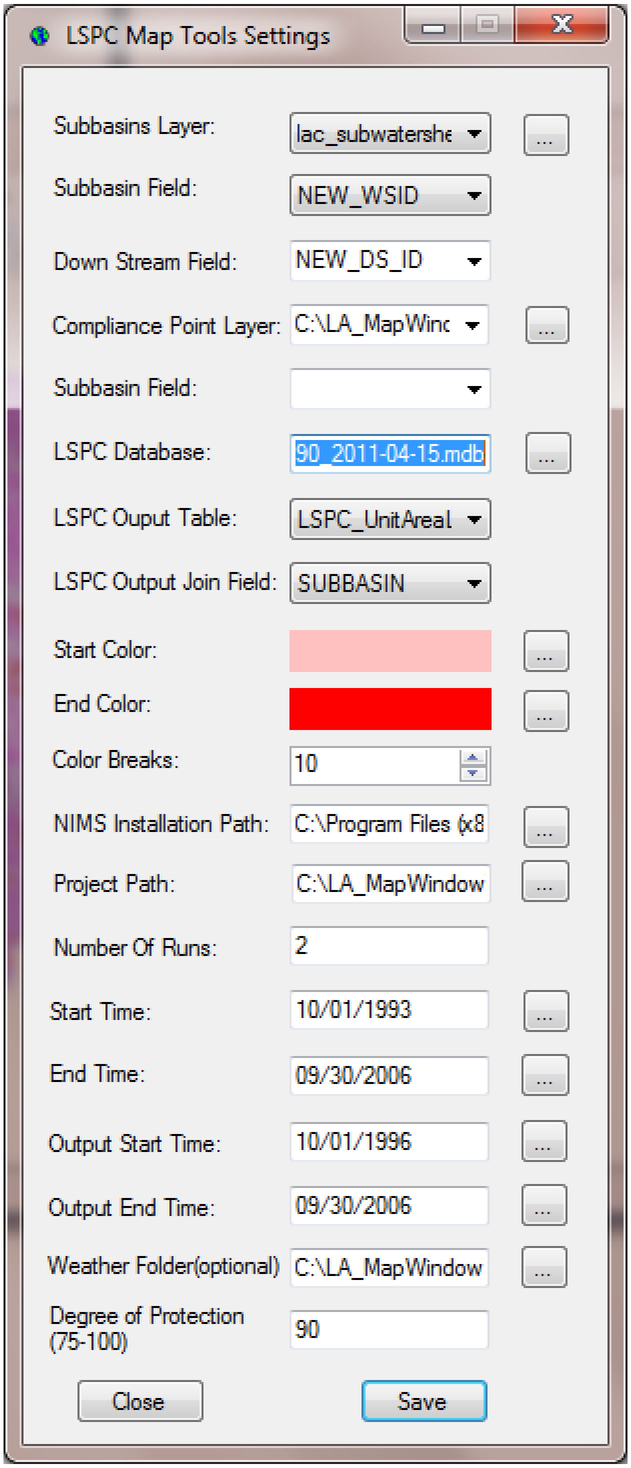


Figure 9. Example input for the LSPC Map Tools Settings.

Step 5: Set subbasin selection option

Click the **NIMS** menu and select **Select subbasins for input into LSPC model**. You should see the prompt as shown in Figure 10. Click **Yes**.

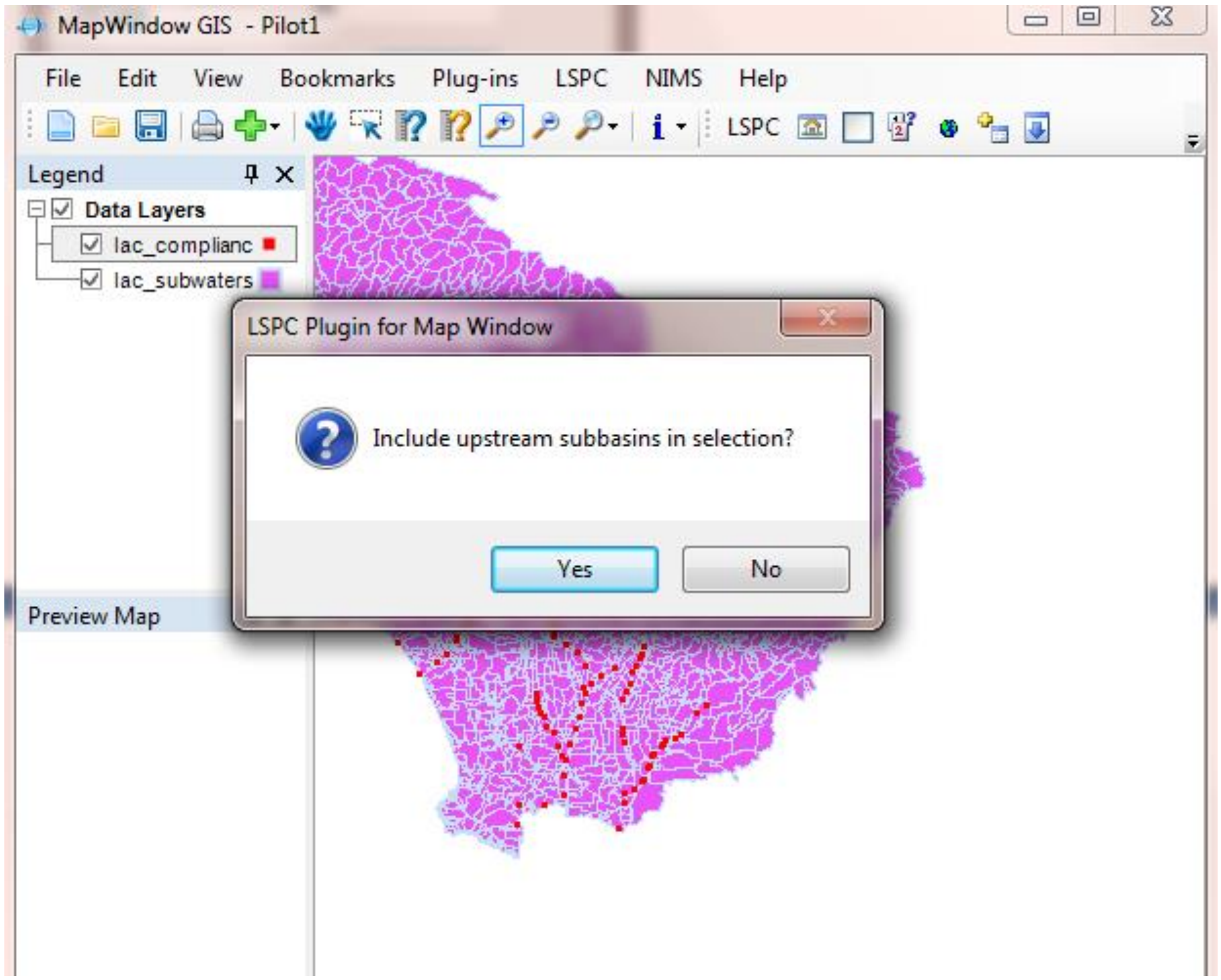


Figure 10. The subbasin selection option window.

Step 6: Select the subbasins for analysis

Click on the subbasin selection icon, which is between the hand (palm) and the question mark icons, point to the area where a simulation-optimization analysis is to be conducted. To select a group of subwatersheds for analysis, use the left mouse button, and click and drag. Note: There must be at least one compliance point in the selected area. Figure 11 shows an example area selected for analysis, which is highlighted in yellow.

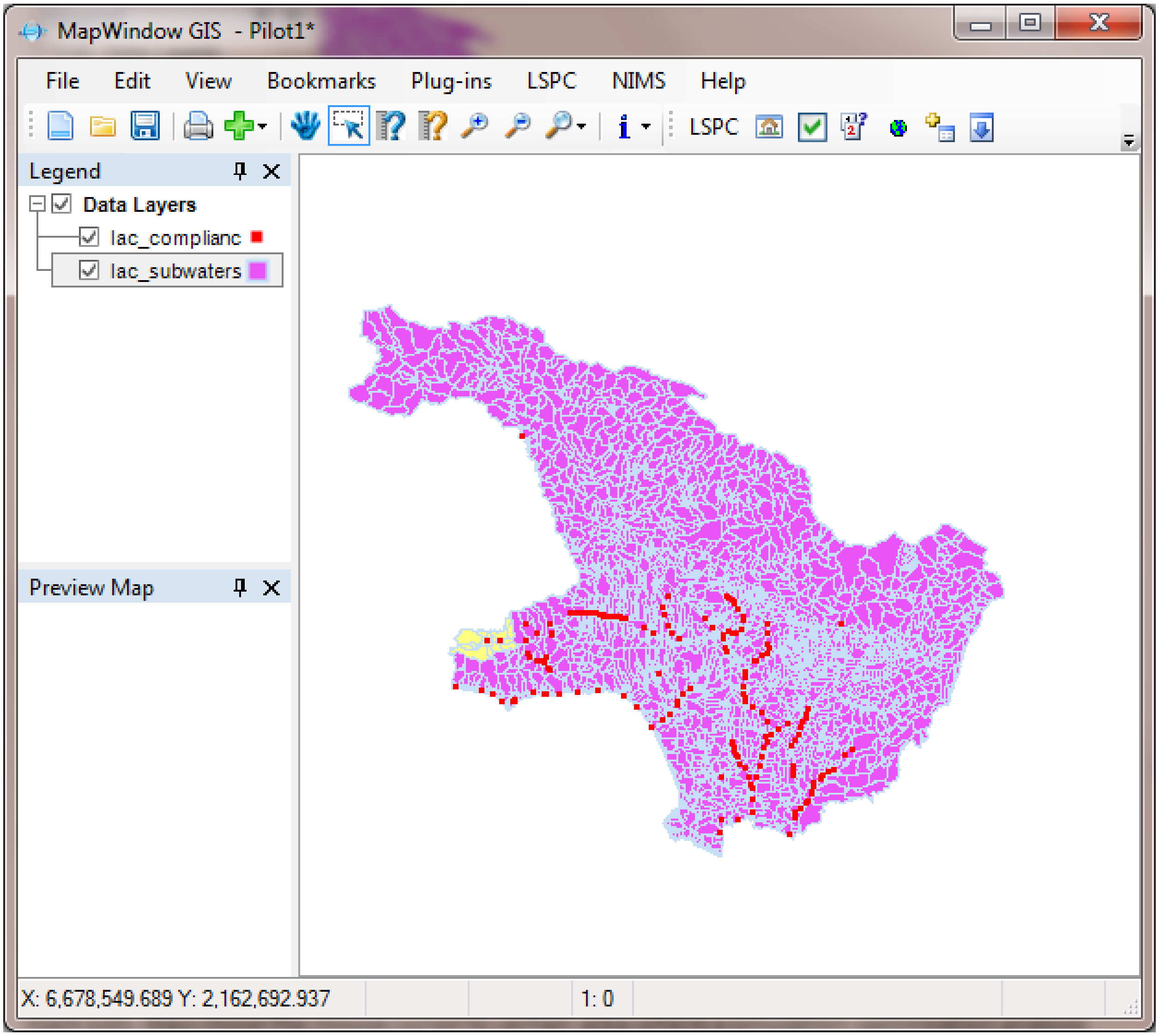


Figure 11. Selected subbasins (yellow area).

Step 7: Save the selected subbasins to a scenario

It is a good practice to save the selected subbasins to a scenario with description, which lets you retrieve the configuration for debugging and testing. To do that, click the **NIMS** menu, then **Create and manage scenarios…**. The scenario window appears as shown in Figure 13. Click the + icon to create a new scenario. For the Scenario Name, type in **Study1** to identify the scenario, and under the Scenario Description, type in the description of the scenario (For example, "Selected subbasins cover two compliance points.") You can type in any relevant scenario name and descriptions here.

Point to the right of **No Action**, click the dropdown arrow, as shown in Figure 12. Select **Update scenario subbasins with map selection**, then click the **Apply** icon just to the right of the Save icon. Click the **Save** icon, then close the window.

In the future, if you want to configure a different analysis using the same subbasins group, click **NIMS**, then **Create and manage scenarios…**, select the scenario name corresponding to the desired subbasin group, click the dropdown arrow by the **No Action** term, click the **Update map subbasins selection with scenario**, and click the **Apply** icon. Doing that selects the subbasins according to the configuration in the previously saved scenario.

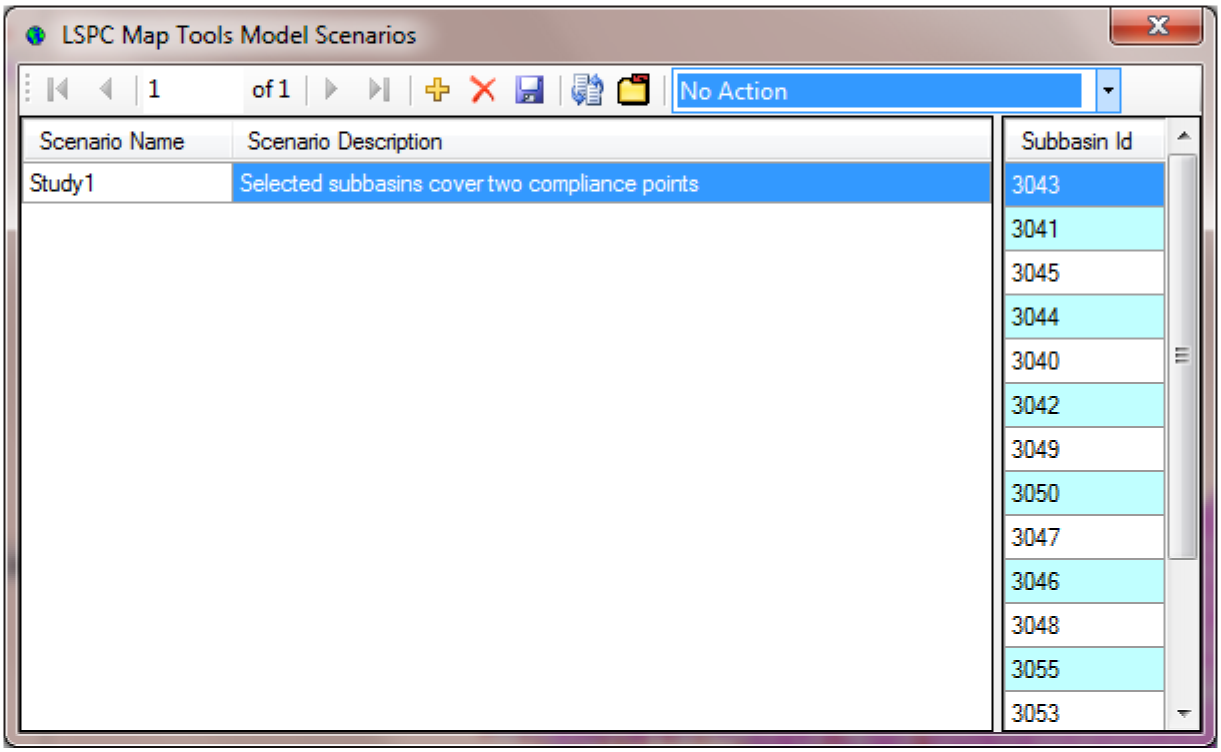


Figure 12. Scenario management window (1)

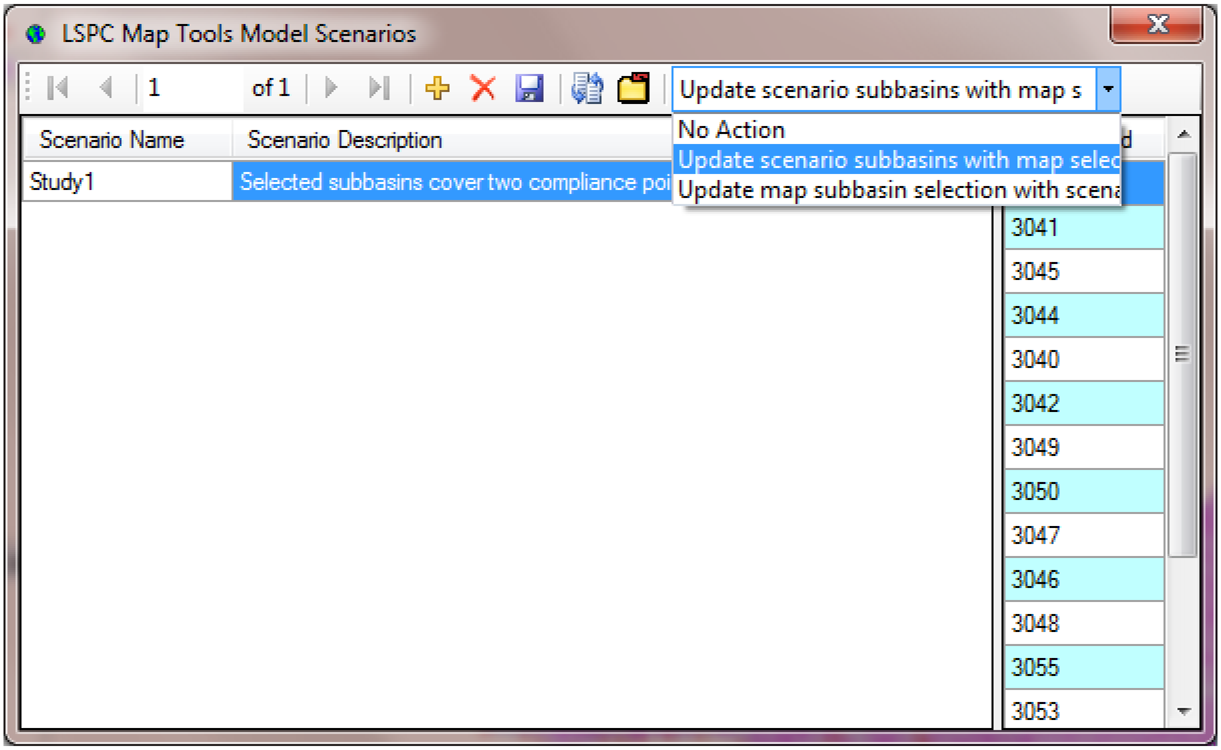


Figure 13. Scenario management window (2)

Step 8: Generate a scenario analysis package

Now generate the analysis package for the selected subbasins. Click **NIMS**, then **Update the excel file…**. The program runs, and the progress bar is shown at the bottom-right portion of the window. When the scenario generation is completed, a “Process Excel Completed!” message displays, as shown in Figure 14.

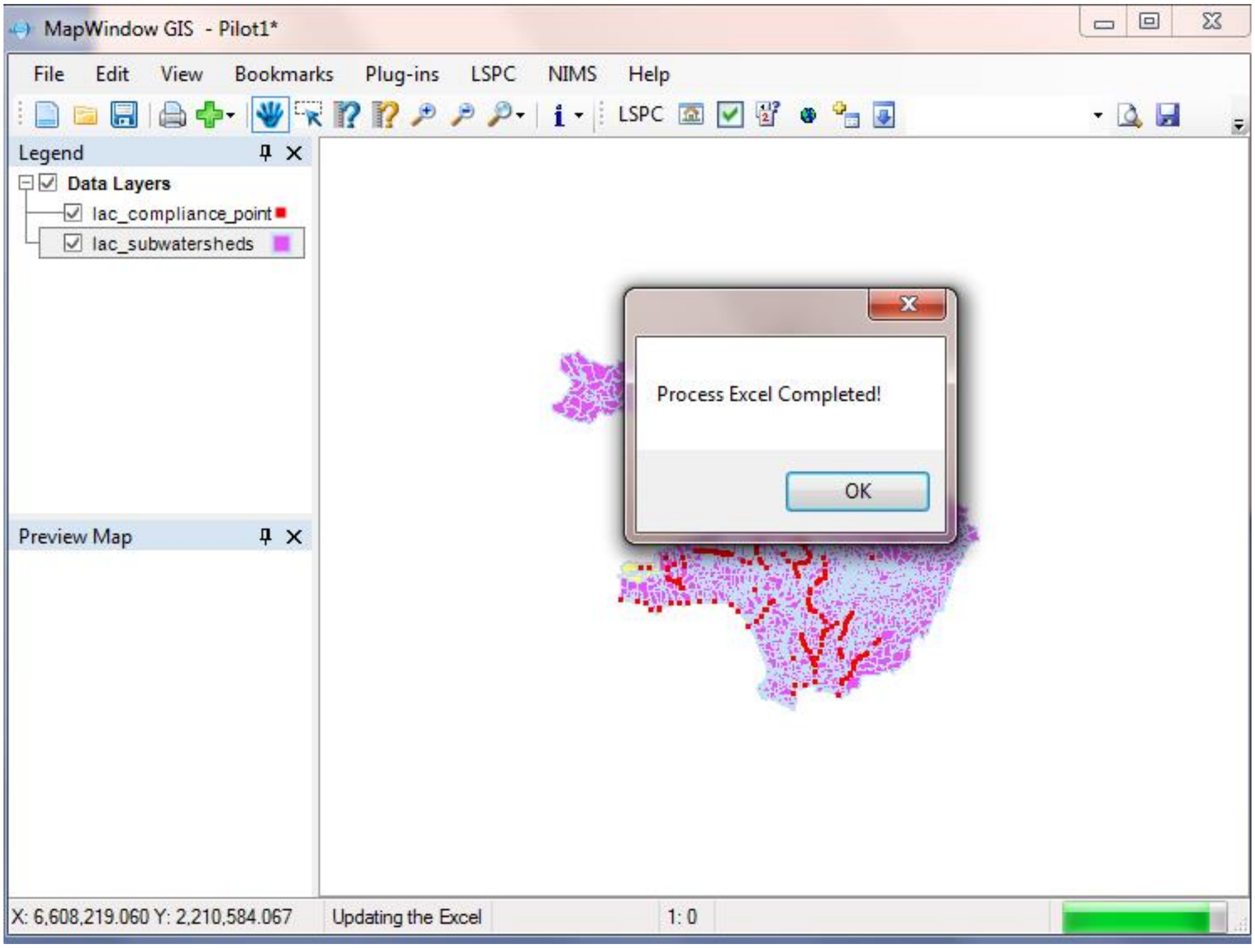


Figure 14. The message after running the scenario generation.

Step 9: Pre-process the simulation-optimization model

After the scenario package is generated, Click **NIMS**, then **Run the pre-processing spreadsheet…**, which starts the preprocessing. This step involves running the LSPC watershed model iteratively to construct the interval response matrix for the NIMS algorithm. Figure 15 shows the interface during pre-processing.

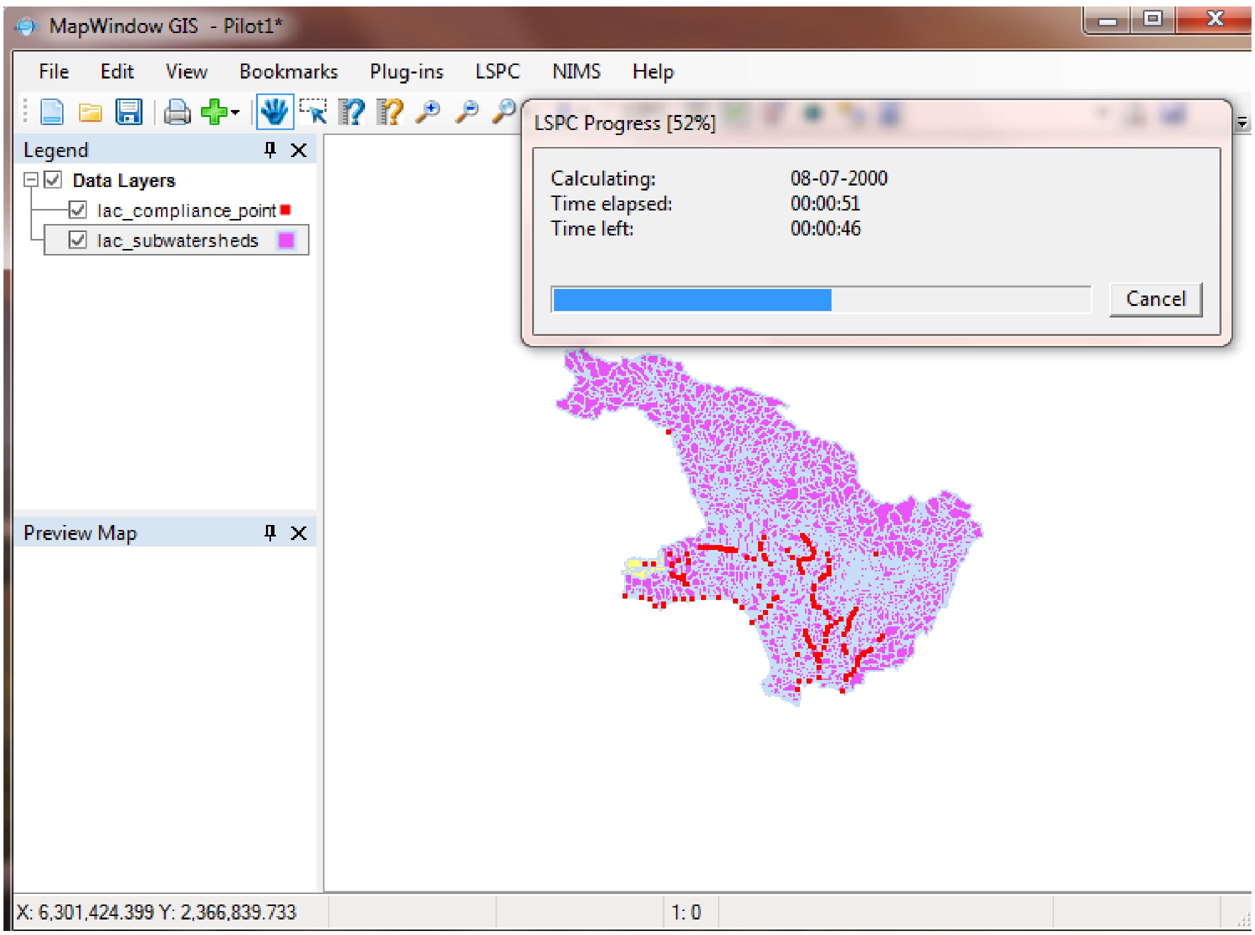


Figure 15. The preprocessing progress.

Step 10: Launch the optimization model

After the preprocessing is completed, the resulting optimization model can be launched by clicking **NIMS** then **Launch the NIMS spreadsheet…**. The interface and data management file `LA_NIMS.XLSM` for the optimization model appears, as shown in Figure 16.

LA_NIMS.XLSM contains the following workbooks:

Main: The main interface for implementing the NIMS algorithm for solving the simulation-optimization model
BaseLoadingSWS: Contains the baseline loading at each subwatershed
BaseLoadingLand: Contains the baseline loading from the land surface of each subwatershed
Scale: Scaling factors used to pre-condition the matrix of the model; generally the pollutants that have lower order of magnitude of loading would be applied a value > 1 to allow their loading values comparable to other constituents with higher loading. The values usually can be set to 1.0 for all constituents without hurting the model solution. The default values are provided in the spreadsheet.
CONS: Contains generated constraints in the NIMS sub-models
Treat_Ratio: Contains ratio relating load reduction of each constituents to volume reduction by implementing BMPs in each subwatershed
Bound_Constraint: Contains lower and upper bound of the allowable reduction rate at each subwatershed
Cost: Contains coefficients of the quadratic cost function of each subwatershed
Solutions: Contains optimal solutions of the intermediate NIMS sub-models
Final_Optimal_Solutions: contains the final optimal solution of the simulation-optimization model
LHSheet: Contains intermediate information during model generation process
Compliance_Loc: Contains loading target at each compliance point
LandUse_ID: Lists the land use ID in the LSPC model
Proportional_Reduction: This workbook is optional, which is used to store the result of independent proportional reduction scenario analysis. Leave it blank if no such analysis is to be conducted.
Regional_BMP: In cases where distributed reduction is not sufficient to meet the loading target, extra loading reduction is required in pounds/yr. The values are obtained in solving the optimization model and will be stored in this workbook.

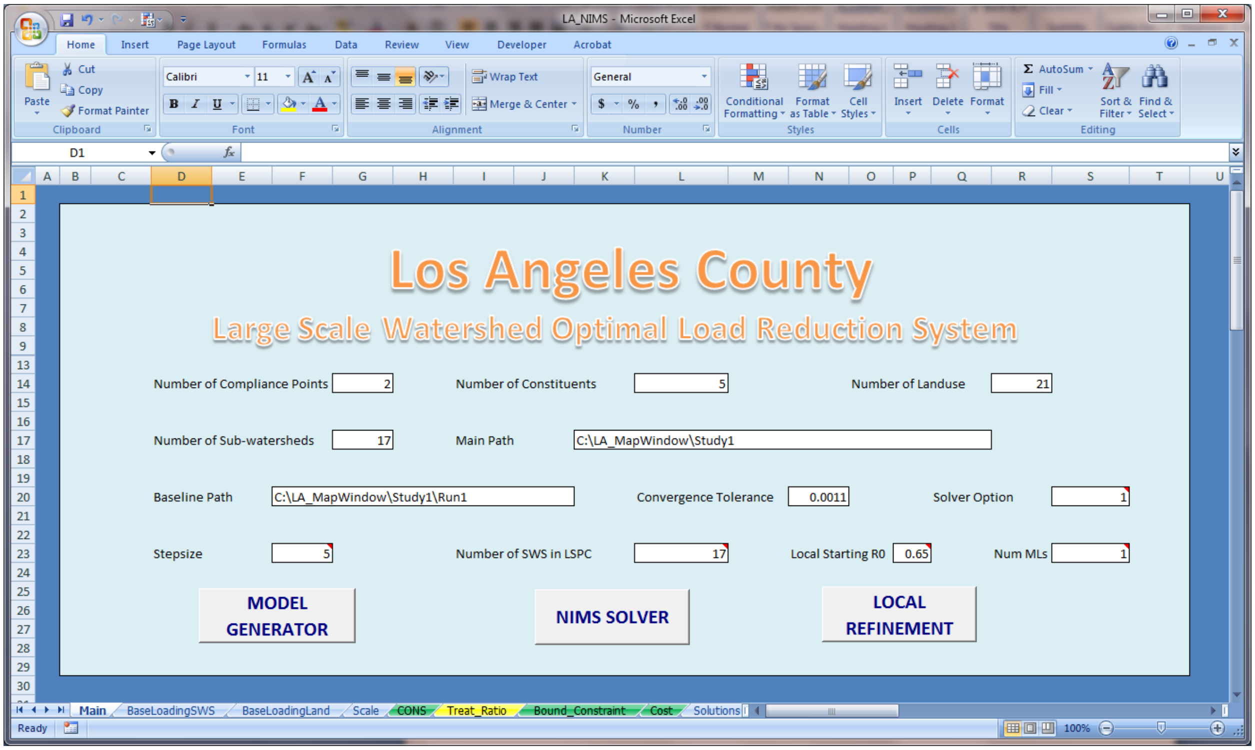


Figure 16. The optimization model interface.

Step 11: Conduct the optimization analysis

First, you must construct an entire model structure of NIMS. To do that, click the **Model Generator** button. This could take several seconds for a small problem or several hours for a large-scale problem.

To start the solution process for the simulation-optimization model, click **NIMS SOLVER**. That process could take less than 1 hour for a small-scale problem, or more than a week of computational time if large areas are selected to form a large-scale problem. Two progress bars show the progress of the solution. One is for the entire NIMS solution process, and the other is for each LSPC running process. An example display of the solution progress is shown in Figure 17, where the “20% in Progress…” is for the NIMS process, and the other is for the LSPC run. The final solutions are stored in the workbook Final_Optimal_Solutions as shown in Figure 18.

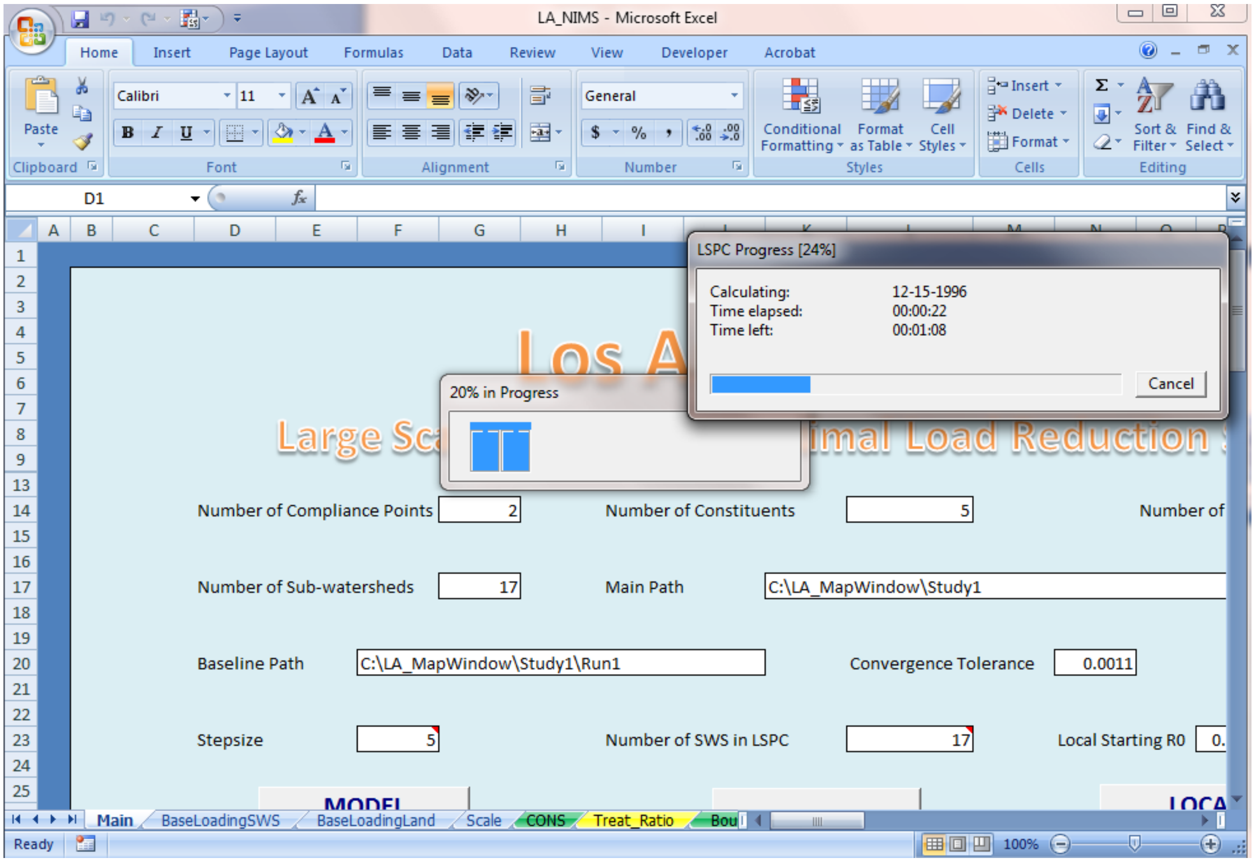


Figure 17. The progress of the optimization process.

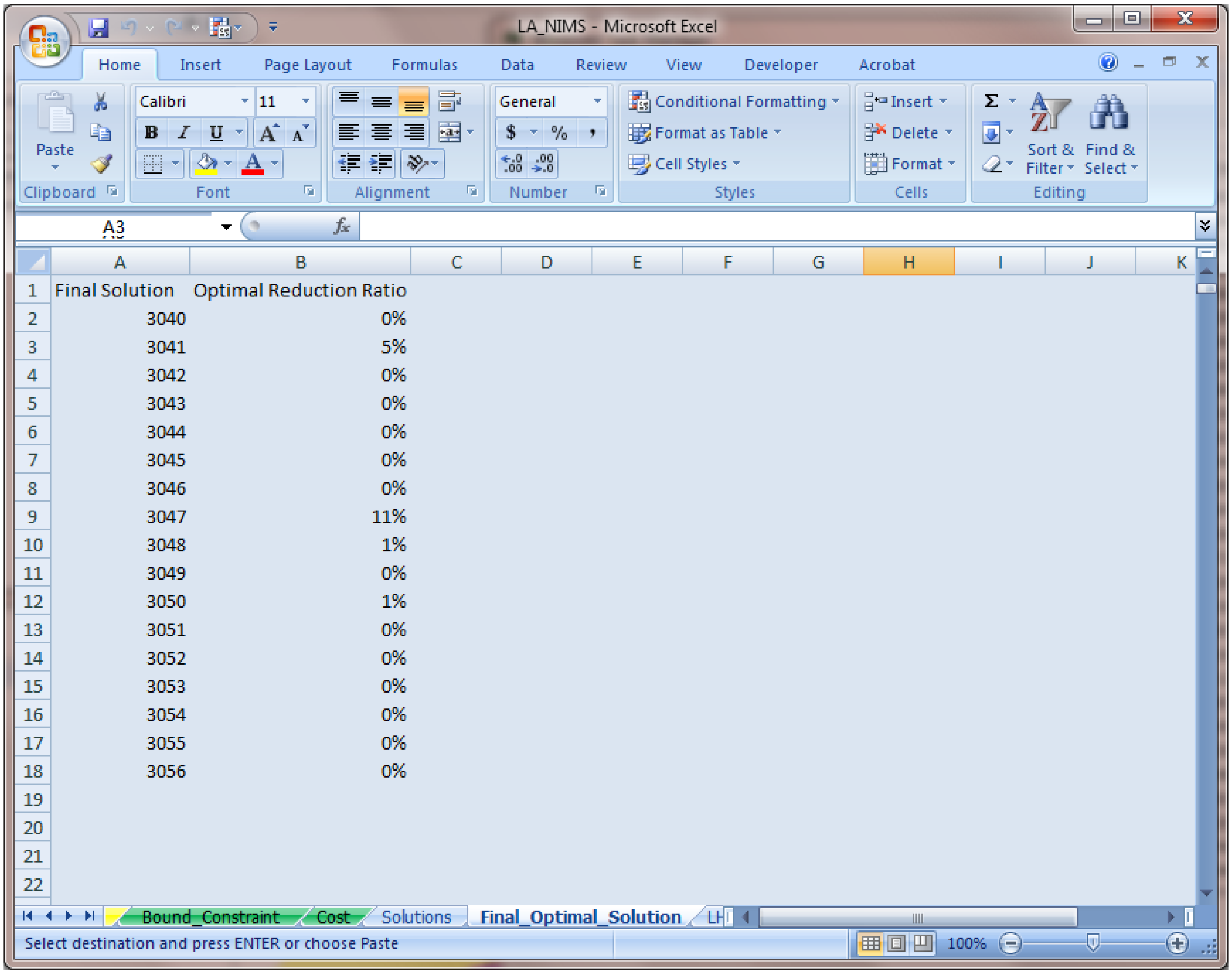


Figure 18. The final optimal solution.

Step 12: Visualize optimization results in MapWindow

After running optimization, the final optimal solution can be viewed in MapWindow in terms of area-normalized treatment depths by subwatershed. From the **NIMS** menu, select the **Import Optimization Result** item, as shown in Figure 19.

In the background, this action will import the final optimal solution from the active NIMS project spreadsheet into the *NIMS_Output* table in the LSPC database file. Inside the database, the *NIMS_Treatment_Depths_Regression* table contains the coefficients and exponents of a regression relationship that relates the flow reduction ratio to treatment depth for each subwatershed. The NIMS_Treatment_Depths query performs the regression calculation to derive treatment depths by subatershed. A new field containing the query result, and named after the current NIMS scenario project folder, is added to the display table (LSPC_UnitAreaLoads).

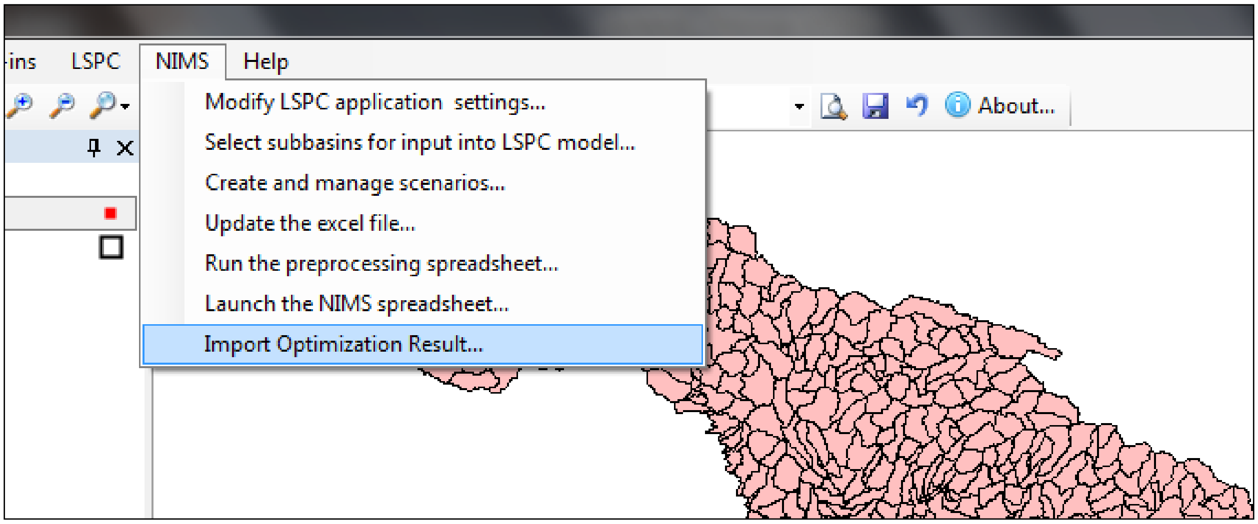


Figure 19. Importing Optimizatin Results.

After invoking the Import Optimization Result command, follow steps 1 through 4 as shown in Figure 20 to display and save the area-normalized treatment depths spatially (by subwatershed). The  icon can be used to reset the map display after visualization.

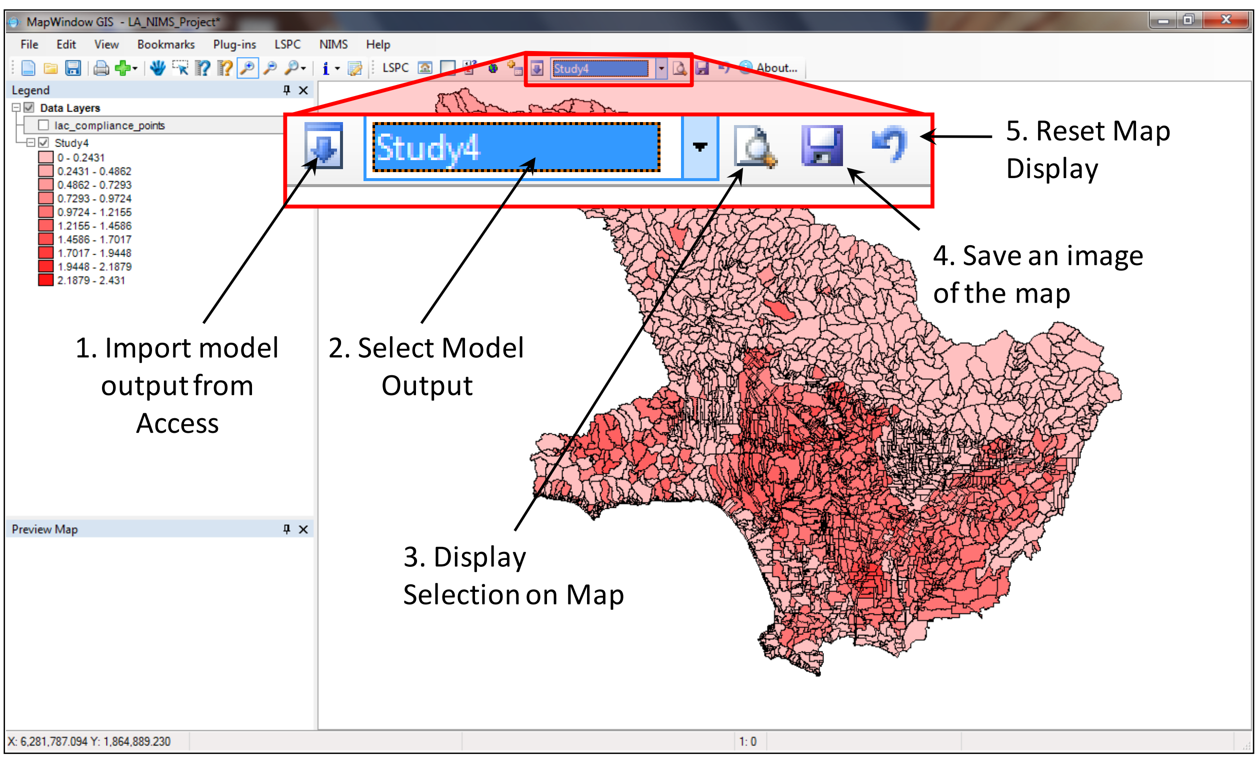


Figure 19. Steps for displaying subwatershed-associated model results on the map.

3. Optional Procedure: Local Refinement

The solutions obtained above can be considered the final optimal solution to be used as basis for implementation decision making. If you want an additional slight improvement, you can execute the following local refinement processes:

Step 1: Identify the starting point for local refinement

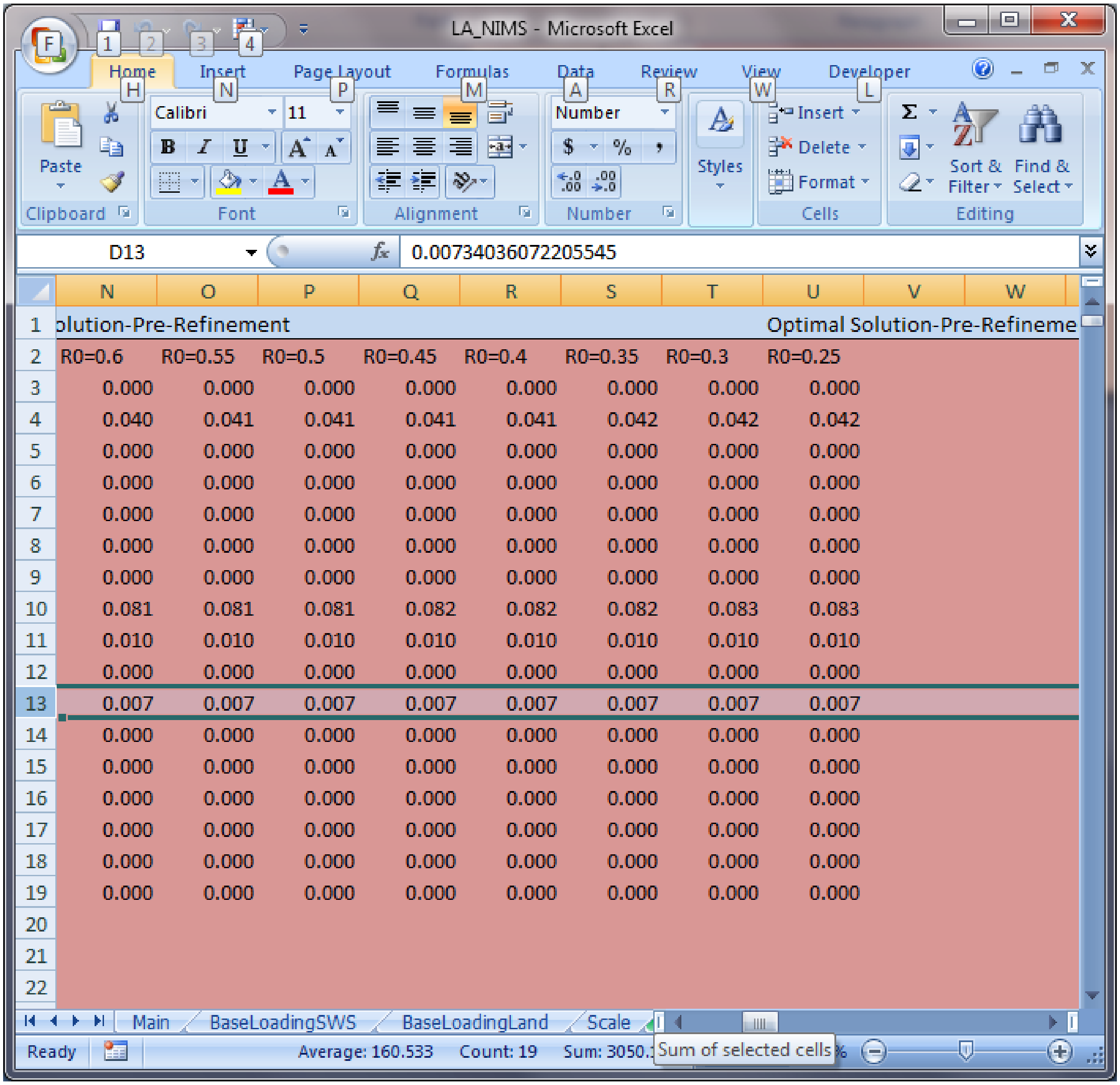
The starting point for the local refinement can be identified through inspecting the **Solutions** workbook (Figure 21). As shown, the columns of the workbook correspond to different intermediate solutions at different R0 values. The lowest R0 value here is 0.25 (Column U). Therefore, the starting point for the local refinement is determined to be the R0 value that is one column to the left, i.e., R0=0.30

Step 2: Input the local refinement starting point

Activate the Main workbook. In the cell to the right of the "Local starting R0," enter a starting point value 0.30 (see Figure 22).

Step 3: Run the local refinement

Click the **Local Refinement** button to start the process. When the process is complete, the Final_Optimal_Solution is updated with the refined solution.
Note: In most cases, the local refinement is NOT recommended because it would incur additional computational burden, while the slight improvement in solution might not make practical difference.



	N	O	P	Q	R	S	T	U	V	W
1	olution-Pre-Refinement							Optimal Solution-Pre-Refineme		
2	R0=0.6	R0=0.55	R0=0.5	R0=0.45	R0=0.4	R0=0.35	R0=0.3	R0=0.25		
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
4	0.040	0.041	0.041	0.041	0.041	0.042	0.042	0.042		
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
10	0.081	0.081	0.081	0.082	0.082	0.082	0.083	0.083		
11	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010		
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
13	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007		
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
20										
21										
22										

Figure 21. The Solutions workbook

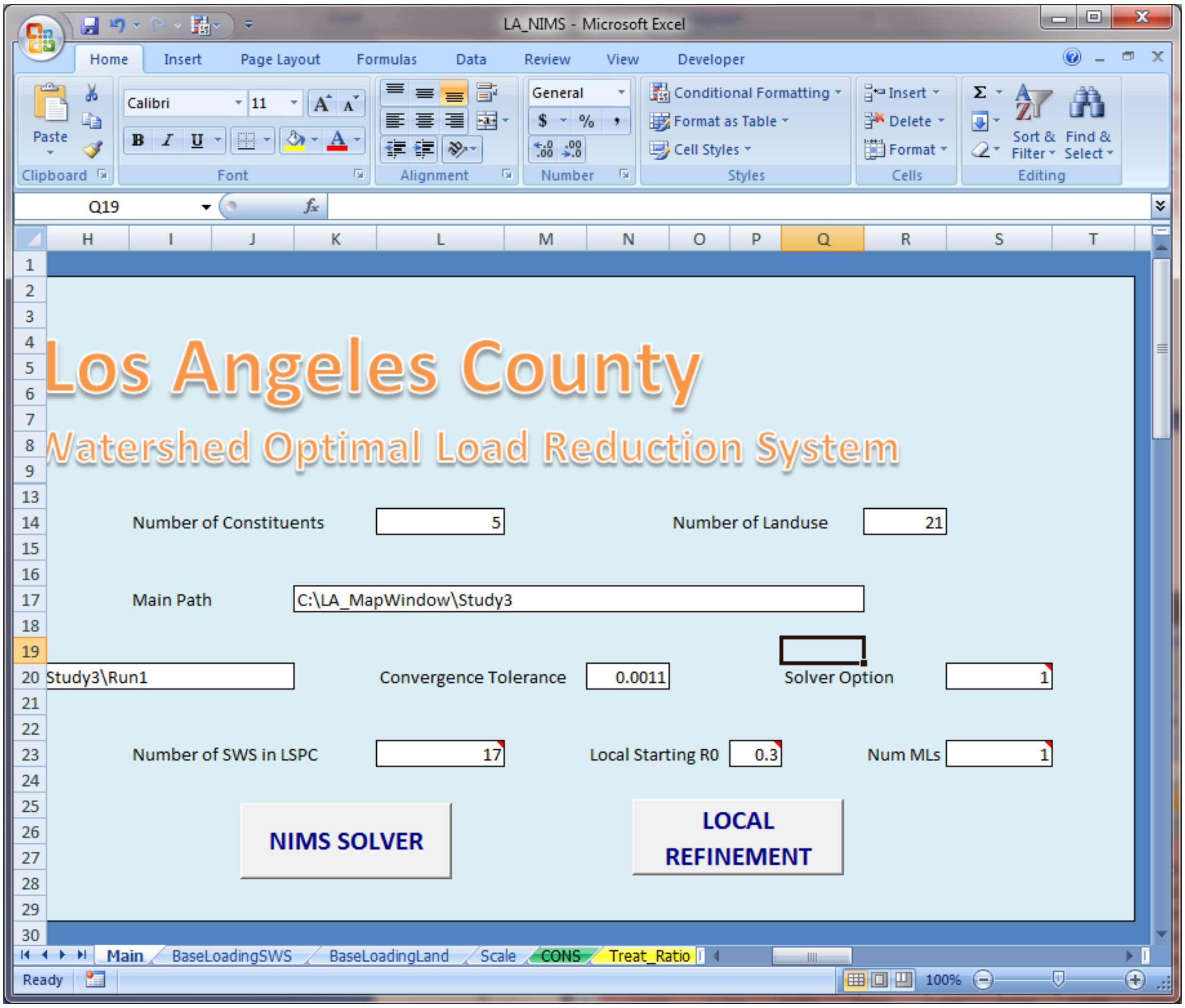


Figure 22. Enter the local refinement starting point

4. References

Zou, R., Y. Liu, J. Riverson, A. Parker, and S. Carter. 2010a. A Nonlinearity-interval mapping scheme for efficient waste load simulation optimization analysis. *Water Resource Research* 46(W08530). doi:10.1029/2009WR008753.

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